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(71) Applicant *(for all designated States except US)*: IMATRAN VOIMA OY [FI/FI]; Malminkatu 16, SF-00100 Helsinki (FI).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)* : HALONEN, Anita [FI/FI]; Mäkitorpantie 42 D 32, SF-00640 Helsinki (FI).

(74) Agent: SEPPO LAINE KY; Lönnrotinkatu 19 A, SF-00120 Helsinki (FI).

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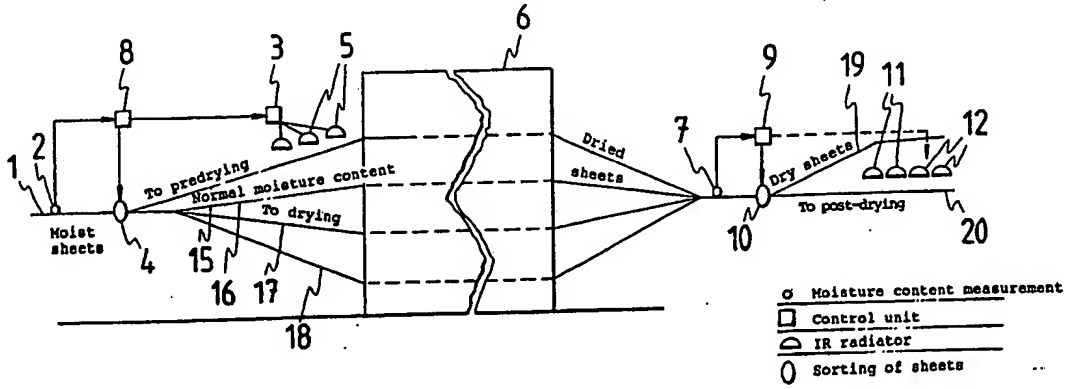
(54) Title: METHOD AND APPARATUS FOR DRYING PLANAR MATERIAL, E.G., VENEER SHEET



(57) Abstract

This publication discloses a method and an apparatus for drying planar material, e.g., wood sheet. In accordance with the method, the main drying phase is implemented by subjecting the material to heat energy exposure, and the moisture content of material to be dried is measured prior to and/or after the main drying phase. In accordance with the invention, material identified in the measurement to be of the highest moisture content is exposed to a first IR radiation with its wavelength of maximum intensity approximately coincident with the wavelength of maximum absorption in water; immediately after the first exposure the material to be dried is exposed to a second IR radiation of a shorter wavelength than the wavelength of maximum intensity in the first radiation; and the energy doses imposed on the material to be dried by both the first and the second radiation are adapted to be at least approximately equal in magnitude. With help of the invention, variations in the moisture content of the material are minimized.

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Method and apparatus for drying planar material, e.g., veneer sheet

The present invention relates to a method for drying planar material, e.g., veneer sheet, in accordance with the preamble of claim 1.

The invention also concerns an apparatus for the implementation of the method.

In the inventions of the prior art, particularly the drying of veneer sheets has been solved by using roll or screen dryers in which the sheet is dried by hot steam. The moisture content of the dried sheets was measured and the sheets of highest moisture content were sorted aside and redried.

A disadvantage of the conventional technique is that the use of a mere roller or screen dryer results in a nonhomogeneous moisture profile which increases the costs and slows down the processing of the final product. Conventional dryers do not lend themselves to adjustments for individual sheets. Consequently, sheets with lower initial moisture content tend to become overdried, that is, subjected to excessive stay in the dryer. Due to overdrying, the quality of sheets deteriorates by embrittlement, which leads to easy breaking in handling stages following the drying process. Although a portion of the sheets is overly dry, yet still another portion may remain excessively moist. In industrial production, the proportion of excessively moist sheets exiting the dryer is about 15 %. The redrying run required by these sheets slows down the process.

The aim of the present invention is to overcome the disadvantages of the prior art technology and to achieve a totally new kind of method and apparatus for drying planar material, e.g., veneer sheet.

The invention is based on the adaptation of two subsequent infrared radiating dryers of different types onto the dryer line such that the wavelength of maximum intensity in the radiation spectrum of the first radiator type coincides at least essentially with the wavelength of maximum absorption in water (and possibly also with that of the material to be dried) while the wavelength of maximum intensity of the second radiator is within the near-IR range (approx. 1 μm), and energy doses from both radiator types imposed on the material to be dried are approximately equal in magnitude.

More specifically, the method in accordance with the invention is characterized by what is stated in the characterizing part of claim 1.

Furthermore, the apparatus in accordance with the invention is characterized by what is stated in the characterizing part of claim 3.

The invention provides outstanding benefits.

The dryer implementation in accordance with the invention has presented decreases in energy cost in some cases. Variations in moisture contents of the product has been reduced to a lower level compared with conventional solutions, allowing, together with the shortened drying time, an increase in the capacity of the dryer.

The invention is next examined in detail with help of an exemplifying embodiment illustrated in the attached drawings.

Figure 1 is a diagram of definitions of wavelength ranges applicable to the implementation of the invention.

Figure 2 is a graph of absorption curves of wood and water, respectively, as a function of wavelength.

Figure 3 shows in an essentially diagrammatic side view a dryer apparatus in accordance with the invention.

Figure 4 shows in a cross-sectioned top view a radiator element in accordance with the invention.

Measurement results described herewithin are based on small-scale experiments that were performed to evaluate the effect of infrared radiation in the intermediate wavelength and near-IR ranges on veneer sheet in preheating and postdrying conditions. The aim of practical tests was to find optimal solutions to the drying process and apparatus construction.

As illustrated in Fig. 1, the spectrum of IR radiation is divided into near-IR (short-wave), intermediate wavelength, and far-IR ranges. Evidenced in Fig. 2 is the coincidence of absorption maxima of water and wood in the intermediate IR range at a wavelength of about 3 μm. From this, one is apt to assume a highest efficiency of both wood heating and water evaporation to be obtained in this wavelength range. Since, however, radiation impinging on a body may experience a total or partial reflection, absorption, or guidance, a drying effect of maximum efficiency will not be achieved by a simple coincidence adaptation of radiation wavelength with the absorption maxima, but rather with a combination dryer in accordance with the invention.

The embodiment of the IR dryer apparatus is based on the subsequent use of intermediate and near-IR range radiation. The sheet is first exposed from an appropriate distance to intermediate range IR radiation and then to near-IR radiation such as to obtain an approximately equal energy doses of impinging radiation onto the sheet. In addition, a rear

reflector capable of improving the IR drying efficiency is adapted to the conveyor used in the IR dryer construction.

In accordance with Fig. 3, the IR dryer apparatus in accordance with the invention can be adapted to a conventional drying process of sheets, either before or after a roll dryer 6. Further, a simultaneous use of a predryer and a postdryer is possible. Controlled by a predetermined moisture categorization, excessively moist sheets are conveyed via an IR dryer either to preheating or to postdrying. Moist sheets are brought on a band conveyor 1 to a moisture measuring system 2, and the sheets are directed by a control unit 8 to an appropriate drying line 15...18. Sheets with highest moisture content are predried by IR preheaters 5 on the line 15. The heaters 5 are controlled by a control unit 3. After predrying, the sheets are conveyed to a roll dryer 6, in which the sheets are dried by hot steam at a temperature of about 180 °C on four different levels. After steam-drying, the sheets are cooled. After exiting the roll dryer 6, the sheets are again measured for moisture content in a measurement apparatus 7, measurement information is fed to a control unit 9 which steers a sorter so that sheets still excessively moist are routed to a post-drying line 20. On the post-drying line 20 the sheets are dried by intermediate IR range radiators 11 and near-IR range radiators 12. Conversely, sheets identified as dry after the roll heater 6 are directed to a processing line 19 for further fabrication.

Figure 4 illustrates a radiation heater construction in which a conveyor 22 carrying sheets to be dried traverses under the heater from left to right. A typical speed for the conveyor is 70...80 m/min. The sized of dried sheets is 1.5 x 1300 x 1410 mm. The heater is divided into two zones approximately equal in area called intermediate IR range zone A and near-IR range zone B. The combined length of the zones A and B in the direction of the conveyor 22 amounts to 1500 mm with a total width of the heater unit being approx. 1550 mm. The intermediate IR range zone A comprises three

groups 21 of dual tubular bulb radiators mounted with approx. 55 mm spacing. The near-IR zone B has six groups of dual tubular bulb radiators mounted with approx. 65 mm spacing. Because all IR heated units must be provided with sufficient air circulation to vent fumes and improve drying, the heater unit in accordance with the figure is equipped with two fans (not shown). The fans are placed atop the heater unit approximately centered to each zone. The flow rate per fan is 50 l/min. This rate maintains fanned air temperature at approx. 30...35 °C. To further improve radiation efficiency, the heater unit is provided with an aluminum back reflector (not shown), whose purpose is to reflect radiation passed through the conveyor 22 back to the sheet. The conveyor 22 moves between the radiator and the back reflector plate.

Figure 3 illustrates experiments performed in practical conditions using IR radiators as preheaters in conjunction with a roll heater 6. Material to be dried was birch sheet. Firwood sheets were also tested and found to require less energy to dry. A majority of the material had a moisture content exceeding 80 %. In approx. 15...18 % of the material, the moisture content was in excess of 90 %. Infrared predrying was performed using in turn intermediate wavelength IR energy alone, near-IR energy alone, or combinations of these so that the first combination had a first unit producing intermediate wavelength IR radiation immediately followed by a second unit producing short wavelength IR radiation while the second combination was identical except for reversed order of units. In each run, the applied power and exposure time were maintained constant.

According to the tests, the most advantageous combination was such a configuration of intermediate and short wavelength IR radiators in which the material to be dried is first exposed to an intermediate wavelength IR radiation whose wavelength of maximum intensity at least approximately coincides with the coinciding maximum absorption wavelengths of water and wood sheet. The final drying is then performed

using short wavelength IR radiation. Input power to both dryer units was approximately equal averaging to 41.5 kW per m^2 of sheet and the exposure time in both zones was 5 s. Due to practical arrangements of test conditions, however, the proportion of energy exposure in the intermediate wavelength unit was 46 % while the rest of the exposure was delivered in the short wavelength unit. The distance of IR radiators to the sheet was 140 mm. Radiators used were dual tubular bulb fused-quartz radiators with gold-plated back reflection layer, manufactured by Heraeus GmbH. The intermediate wavelength dual bulb radiators used were characterized as: radiating section length 1300 mm, cross-section 33/15 mm^2 (outer/inner), power 3250 W, and emission wavelength range 1.5...6.0 µm with a maximum at about 3 um. Respectively, the short-wavelength dual tubular bulb radiators were characterized as: radiating section length 1300 mm, cross-section 23/11 mm^2 (outer/inner), power 7000 W, and emission wavelength range 0.5...2.5 µm with a maximum at about 1.2 µm. Wavelength specifications referred to above are applicable at maximum nominal power. The maximum exposure time used was 6 s per zone.

Application of predrying decreased moisture content in a sheet lot by 5.0...9.7 percent units. The average decrease in moisture content was 7 percent units. A combination drying procedure achieved a 10 % increase in drying capacity in comparison with conventional drying methods. The drying time was decreased by 10 %. Electric energy amounted to 14 % of energy consumption in the process. Total energy consumption was decreased by approx. 10 %.

In a second experiment the combination of a roll dryer and IR postdrying was tested. When IR radiation is used for postdrying, all sheets with a moisture content in excess of 5...6 % are to be sorted to IR drying.

The IR postdrying tests were run using same wavelength combinations as in the predrying test resulting in an

equivalent advantageous combination. The average power used was 43.3 kW/m^2, of which 48 % was delivered in the intermediate wavelength radiation unit. The maximum exposure time used was 6 s per zone.

The postdrying process was performed on sheets with initial moisture contents of either approx. 10 % or approx. 15 %. Application of IR drying decreased moisture content in an average by 6.0 and 7.9 percent units, respectively. The tested combination of power/speed in realistic industrial conditions sufficient to dry overly moist sheets rendering an increase of 15 % in drying capacity. Electric energy amounted to 13 % of energy consumption in the process. Total energy consumption was decreased by approx. 30 %.

Evaporative drying applied using other methods was less effective in comparison with the combination intermediate/short-wave IR drying. In addition, the combination short-wave/intermediate wavelength IR drying presented sheet bulging with equivalent process parameters.

The disclosed invention is also applicable to be used in conjunction with a screen dryer.

WHAT IS CLAIMED IS:

1. A method for drying planar material, e.g., wood sheet, in which method

- the main drying phase is implemented by exposing the material to be dried to heat energy, and

- measuring the moisture content of the material to be dried prior to and/or after the main drying phase,

c h a r a c t e r i z e d in that

- material identified in the measurement to be of the highest moisture content is subjected to a first IR radiation, whose wavelength of maximum intensity is at least approximately coincident with the wavelength of maximum absorption in water,

- immediately after the first exposure the material to be dried is exposed to a second IR radiation of a shorter wavelength than the wavelength of maximum intensity in the first radiation, and

- the energy doses imposed by both the first and the second radiation on the material to be dried are arranged to be at least approximately equal.

2. A method in accordance with claim 1, c h a r a c t e r i z e d in that the wavelength of maximum intensity in the first radiation is arranged to be approx. 3 µm and the wavelength of maximum intensity in the second radiation is adapted to be approx. 1 µm.

2. An apparatus for drying planar material, e.g., wood sheet, comprising

- a roll (6) or screen dryer, in which the material to be dried can be dried with steam,

- a conveyor (1) by means of which the material to be dried can be transferred into the roll dryer (6),

- measurement devices (2, 7) by means of which the moisture content of the material to be dried can be measured, and

- control and sorting units (4, 8) by which material identified to be of the highest moisture content can be sorted from rest of the material,

characterized by

- infrared radiators (5, 11, 12) by means of which such material as identified to be of the highest moisture content can be first exposed to a first IR radiation whose wavelength of maximum intensity is approximately coincident with the wavelength of maximum absorption in water, and immediately after the first exposure, the material is exposed to a second IR radiation of a shorter wavelength than the wavelength of maximum intensity in the first radiation so that the energy doses imposed on the material to be dried by both the first and the second radiation are arranged to be at least approximately equal in magnitude.

4. An apparatus in accordance with claim 3, characterized in that reflectors are adapted to oppose the IR radiators (5, 11, 12) behind the conveyor in order to improve the efficiency of exposure to radiation.

5. An apparatus in accordance with either of claims 2 or 3, c h a r a c t e r i z e d in that the IR radiator is comprised of an intermediate wavelength zone (A) comprising a plurality of fused-quartz radiators of intermediate wavelength IR energy, adapted essentially transverse with respect to the transportation direction of the conveyor (1), and a short-wavelength zone (B) comprising a plurality of fused-quartz radiators (23) of near-IR range energy, adapted essentially transverse with respect to the transportation direction of the conveyor (1).

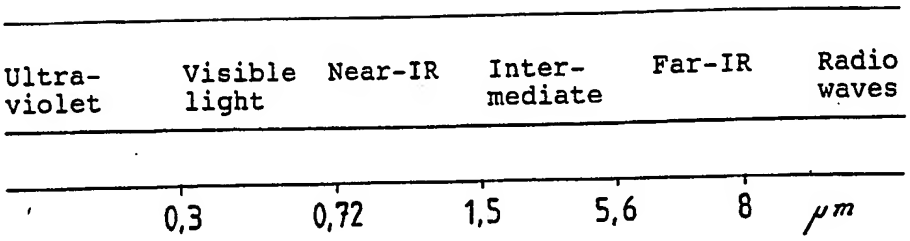
Ultra-violet
Visible light
Near-IR
Inter-mediate
Far-IR
Radio waves
0,3
0,72
1,5
5,6
8
μm

Fig.1

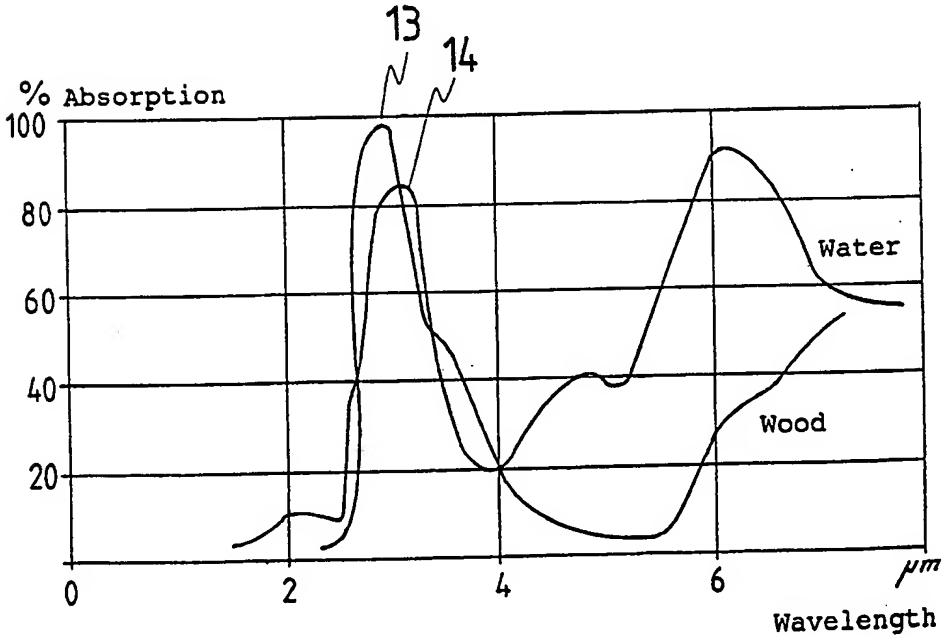
13
14
% Absorption
100
80
60
40
20
0
2
4
6
μm
Wavelength
Water
Wood

Fig. 2

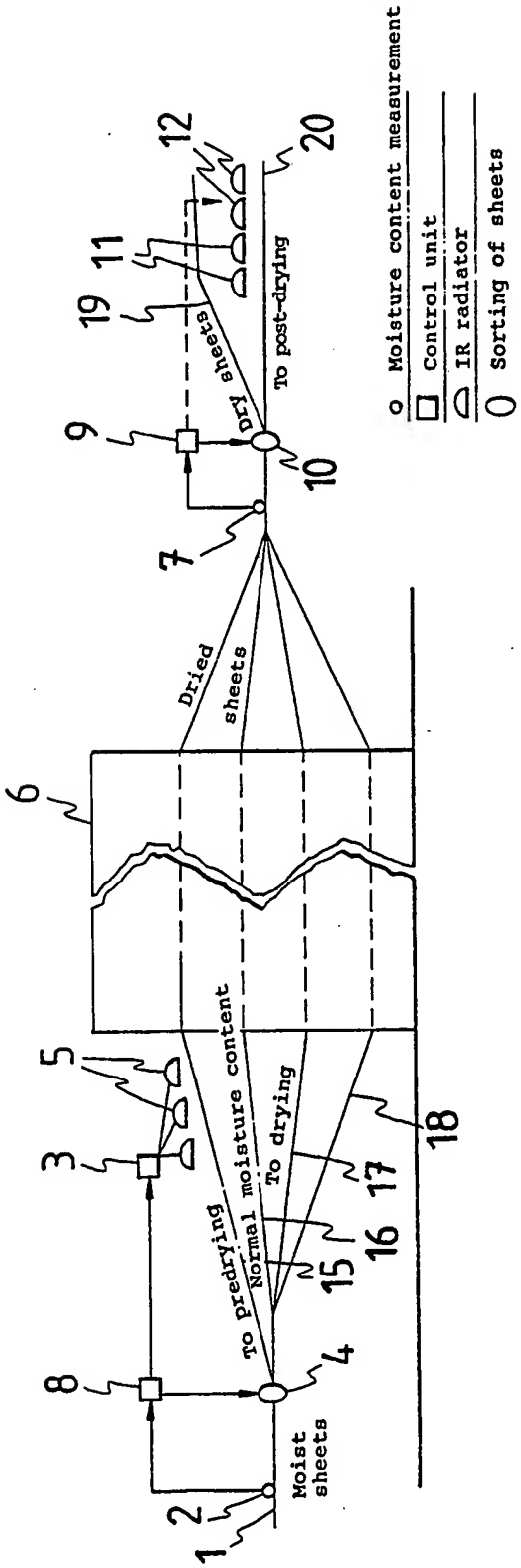
Moisture content measurement
Control unit
IR radiator
Sorting of sheets
Moist sheets
To predrying
Normal moisture content
To drying
Dried sheets
dry sheets
To post-drying
1
2
3
4
5
6
7
8
9
10
11
12
15
16
17
18
19
20

Fig.3

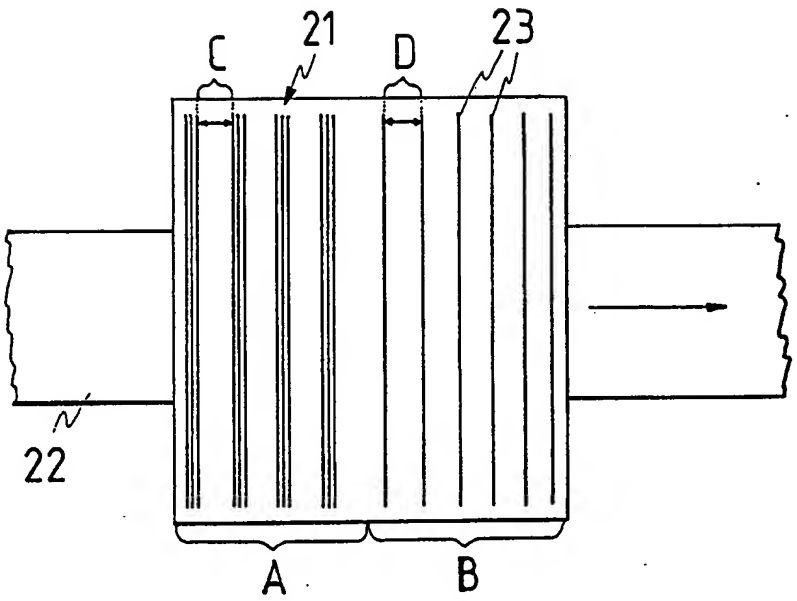

Fig. 4

INTERNATIONAL SEARCH REPORT

International Application No PCT/FI88/00072

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC 4

F 26 B 3/30, 13/10

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC 4	D 21 F 5/16; F 26 B 3/30, 13/10, 23/04, 23/06
US Cl	34:4, 39-41, 68

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [8]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	US, A, 4 565 917 (EDWARD J FURTEK) 21 January 1986	
A	US, A, 3 972 127 (TOYOHIKO HOSHI ET AL) 3 August 1976	
A	US, A, 3 499 231 (T F MULLANEY) 10 March 1970	
A	US, A, 4 594 795 (ERIK STEPHANSEN) 17 June 1986	

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1988-07-20	1988 -08- 11
International Searching Authority	**Signature of Authorized Officer**
Swedish patent Office	Björn Salén Björn Salén

Form PCT/ISA/210 (second sheet) (January 1985)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
Ström & Gulliksson IPC AB
P.O. Box 4188
203 13 Malmö

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	22-09-2004
Applicant's or agent's file reference W 5040-002 LK/md	**FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/SE 2004/001214	19-08-2004	21-08-2003

International Patent Classification (IPC) or both national classification and IPC
F26B3/30

Applicant
Eriksson Kertu et al

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further opinions, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/SE	Authorized officer
Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. +46 8 667 72 88	Nils Nordin/Els Telephone No. +46 8 782 25 00

Form PCT/ISA/237 (cover sheet) (January 2004)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/SE 2004/001214

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This opinion has been established on the basis of a translation from the original language into the following language _____, which is the language of a translation furnished for the purposes of international search (under Rules 12.3 and 23.1(b)).

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material

      ☐ a sequence listing

      ☐ table(s) related to the sequence listing

   b. format of material

      ☐ in written format

      ☐ in computer readable form

   c. time of filing/furnishing

      ☐ contained in the international application as filed.

      ☐ filed together with the international application in computer readable form.

      ☐ furnished subsequently to this Authority for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/SE 2004/001214

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	7-10, 12-14, 17 and 18	YES
	Claims	1-6, 11, 15, 16 and 19	NO
Inventive step (IS)	Claims		YES
	Claims	1-19	NO
Industrial applicability (IA)	Claims	1-19	YES
	Claims		NO

2. Citations and explanations:

The object of the invention concerns a method and apparatus for dehumidifying different material, primarily sewage sludge.

The following documents are cited in the International Search Report:

D1: WO 0237043 A1
D2: US 5678323 A
D3: WO 8808949 A1
D4: FR 2695196 A1

D1 reveals a method and an apparatus for drying wood (3). The drying takes place in a closed drying chamber (1) with the aid of elements (2) which emit radiation energy. The radiation is of such wavelength that it is absorbed by the water molecules in the wood, while the remainder of the wood is substantially unaffected. (See abstract.)

D2 shows a method and drying apparatus for drying a quantity of sludge with a plurality of infrared emitters. The thermal drying of the sludge is controlled with radiant energy and the wavelengths of the radiant energy produced the infrared emitters are in the range between 2,5 and 3,5 microns. (See abstract and claims 1-3.)

D3 describes a method and an apparatus for drying planar material, e.g., wood sheet. In accordance with the method, the main drying phase is implemented by subjecting the material to heat energy exposure, and the moisture content of material to be dried is measured prior to and/or after the main drying phase. .../...

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of: V (1 of 3)

In accordance with the invention, material identified in the measurement to be of the highest moisture content is exposed to a first IR radiation with its wavelength of maximum intensity approximately coincident with the wavelength of maximum absorption in water; immediately after the first exposure the material to be dried is exposed to a second IR radiation of a shorter wavelength than the wavelength of maximum intensity in the first radiation; and the energy doses imposed on the material to be dried by both the first and the second radiation are adapted to be at least approximately equal in magnitude. (See abstract.)

D4 relates to a procedure for drying paint, which uses absorption of infrared radiation with wavelengths lying outside the visible range. The radiation is produced by electrically heating a conductor placed against a surface, which is selectively absorbent to certain wavelengths of radiation. (See abstract.)

D1 and D2 represent the most relevant prior art.

D1 reveals a method and apparatus for drying wood (3). The drying takes place in a closed drying chamber (1) with the aid of elements (2) which emit radiation energy. The radiation is of such wavelength that it is absorbed by the water molecules in the wood, while the remainder of the wood is substantially unaffected. The method characterized in that the radiation is concentrated to exact wavelength ranges where the water has absorption coefficient greater than approx. 1,000cm^{-1}, while the radiation is reduced in other areas and to the wavelength ranges of approx. 6-7 and approx. 10-20 micrometer, while the radiation in the intermediate range, i.e. approx. 7-10 micrometer is reduced. (See abstract and claims 1-3.)

Consequently, claims 1-3 lack novelty.

.../...

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of: V (2 of 3)

The drying apparatus, according to D1, is equipped with an indicator for measuring the temperature in the drying chamber and/or of the air which departs from and/or is fed to the drying chamber. In addition, there are indicators which measure the temperature of the wood. As a rule, the temperature is measured inside the wood and, in certain embodiments, indicators which measure the temperature of the wood. In certain embodiments, there are also indicators which measure the moisture ratio of the wood. This is generally measured inside the wood. Often, the indicators are placed in the centre of the wood, but this is not necessary since account is taken of the placing of the indicators when regulating the drying process.
In order to measure the moisture in the wood, use is made, in certain embodiments, of a weighing machine where the difference between the measured weight and the weight of an ideal, dried wood gives the relevant moisture ratio. (See page 6, lines 5-27.)

Accordingly, claims 4-6 lack novelty.

The drying chamber, according to D1, includes at least one element disposed in the drying chamber for emitting thermal radiation at wavelengths at which the absorption of radiation by the water is great. A fan is provided for the circulation of air in the drying chamber, indicators are provided for sensing the temperature and/or moisture ratio in the wood and temperature and/or the relative humidity of the air in the drying chamber and that a control system (PLC system) is provided for controlling the elements and the fan. (See claim 8.)

Consequently, claim 15 lacks novelty.

.../...

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of: V (3 of 3)

Dependent claims 7-14 and 16-19 do not appear to contain any additional features which, in combination with the features of any claim to which they refer, involve an inventive step, since said features come within the scope of the customary practice followed by persons skilled in the art.

Accordingly, claims 7-14 and 16-19 lack an inventive step.

In light of the arguments stated above, the invention according to claims 1-6, 11, 15, 16 and 19 is not novel. The invention according to claims 7-10, 12-14, 17 and 18 is not considered to involve an inventive step.